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REPORT OF THE MOD AEROSPACE NDT SUB-COMMITTEE (1ST).(U)

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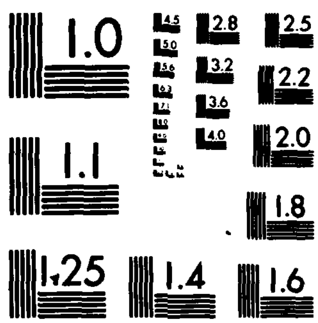

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ROYAL AIRCRAFT ESTABLISHMENT

FIRST REPORT OF THE MOD AEROSPACE NDT SUB-COMMITTEE

This report has been prepared from contributions by
Members of the above Sub-Committee, and
edited by Dr D.E.W. Stone,
RAE, Farnborough

October 1979

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SUMMARY

The establishment of a working party on aerospace NDT problems and its subsequent conversion into a Sub-Committee of the MOD Co-ordinating Committee for NDT is described. A number of problem areas are discussed and actions taken towards their solution are outlined. Other activities of the Sub-Committee are summarised and some techniques that are considered to have potential are identified. Brief conclusions are drawn and some recommendations are made.

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REPORT OF THE MOD AEROSPACE NDT SUB-COMMITTEE

1 INTRODUCTION

The problems of developing and applying effective and reliable methods of non-destructive testing to aerospace structures have steadily increased over the last decade. For new designs these problems have largely arisen through the introduction of a damage tolerant design philosophy and of higher strength materials, whilst for aircraft in service there is a continuing move towards life extension bringing with it the need to detect, quantify and monitor various forms of defect. Thus, as a result of urgent representations from both the SBAC and the RAF, a 'Working Party on future aerospace R&D needs in NDT' was set up in March 1976, with the following objectives:

i to define the problem areas as closely as possible, including giving an order of priority,

ii in the light of these problems, to review current techniques and various phenomena with NDT potential, and

iii to recommend lines of research leading towards more effective and more economical NDE.

The Working Party reported to the MOD(PE) Co-ordinating Committee for NDT and its original Terms of Reference are listed in Appendix 'A'. A total of five meetings were held during the period May 1976 to September 1977 and two interim reports[1,2] were presented to the parent committee. These reports showed how the problem areas had been defined and priorities established; they also outlined progress on research programmes aimed at providing solutions to the more urgent problems and indicated techniques that were considered to have the most potential for aerospace applications. Thus by this stage the Working Party had largely attained the objectives, as defined in its Terms of Reference, but it was clear that if progress were to be maintained there was a continuing need for a body which would act as a general monitor and co-ordinator of aerospace NDT research and serve as a centre of information exchange. In October 1977 therefore the parent committee agreed that two additional Terms of Reference should be adopted (see Appendix 'A') and that, in recognition of the longer term function now being undertaken, the Working Party should change its title to the 'Aerospace NDT Sub-Committee'. This Sub-Committee has held three meetings to date and its current membership is listed in Appendix B.

This report will review the activities of both bodies, outlining the problem areas and describing the progress made on the various research programmes which have been initiated during this period. It will also describe how small Action Groups have been set up to expedite progress in the different areas and report the findings of a number of meetings on specialist topics to which outside experts were invited. For convenience the term 'Sub-Committee' will be used throughout the remainder of this report even though it may in fact have been entitled 'Working Party' at the time in question.

2 RANGE OF PROBLEMS CONSIDERED

The term 'Aerospace NDT' is open to a widely differing range of interpretations but the Sub-Committee considered that it could be most effective if it initially restricted itself to consideration of methods of inspecting defects in structural components of fixed and rotary wing aircraft, together with some related problems on aero-engines. The question of how best to ensure good liaison with NDT activities on gas turbines was considered at some length, and, with the agreement of DG Eng, DD/R&D (NGTE), DR/Mat and Air Eng 32 (RAF), it was decided to set up a Gas Turbine Action Group which

would report to the Sub-Committee. Enquiries made by the SBAC Members of the Sub-Committee failed to discover any NDT problems in the structural side of the weapons field that were not already being covered by the Sub-Committee. A decision was taken, however, to exclude consideration of other NDT problems such as those of hydraulic, electrical and fuel systems or topics such as engine or gearbox health monitoring.

In the subsequent sections the structural problems will be discussed first, followed by a comparative examination of the gas turbine problems. Finally consideration will be given to some techniques which are considered to have potential for development but which have application to more than one type of problem.

3 PRINCIPAL CURRENT PROBLEM AREAS (IN ORDER OF PRIORITY)

3.1 Detection and Sizing of Small Cracks Beneath Installed Fasteners and in Multi-laminate Constructions

It has been estimated by the USAF that cracks that initiate around highly stressed fastener holes are responsible for more than 50% of all aircraft structural failures[3]. It is at present extremely difficult to detect such cracks until they are of sufficient size to emerge from beneath the head of the fastener, and for many critical locations it is necessary to remove the fastener and use eddy current bore hole probes in order to detect cracks before they become critical (the efficacy of such probes will be discussed in Section 3.2). Not only is such a procedure very time consuming but removal of the fastener may in fact introduce scratches etc which act as stress raisers in a previously undamaged hole. There is a requirement to detect cracks less than 1 mm deep situated in either the parallel or countersunk sections of the outer skin or in the second layer. There is also a related but less pressing requirement to detect somewhat larger cracks in third or subsequent layers.

The Action Group set up on this topic decided that whilst it was first necessary to evaluate those techniques that were currently available in commercial or prototype form, and if possible to obtain estimates of the levels of reliability and % confidence, this should not be allowed to delay the development of new techniques. This evaluation has in fact proved rather difficult and is effectively now being performed in parallel with the development of new methods. The difficulty is one that is common to most of the problem areas and lies in the fact that to obtain a calibration of a given technique only two approaches are possible.

i Is to find structural samples containing representative defects and to specify as closely as possible the response of the NDT instrument. It is then necessary to dismantle and cut up the specimen to ascertain exactly what type of defect was present.

ii Is to produce defects in a series of laboratory specimens (not necessarily in a controlled fashion) and to apply NDT and destructive inspection until an adequate calibration has been obtained; then to build specimens containing calibrated defects into a structural configuration.

The actions taken to date may be summarised as follows:

a. Structures Department, RAE, has produced a limited range of specimens in which fatigue cracks have been grown from controlled origins in bore holes of various diameters. These are primarily intended for the programme described in Section 3.2 but some of the holes have been countersunk, allowing bolted joints containing various defects to be assembled.

b. A small number of structural components expected to contain representative cracks have been obtained.

c. An MOD contract has been placed with BAe (Brough) and a range of multi-hole tensile specimens which have been subjected to varying degrees of fatigue damage have been produced.

d. Pantatron Systems Limited have produced a prototype computer-based ultrasonic scanning system which, if placed close to a fastener hole, will automatically centre itself; it will then scan around the hole and display defect signals on a storage oscilloscope. The ultrasonic techniques are conventional but this system should prove to be more accurate than hand held problems and will of course considerably reduce operator fatigue. A number of developments are possible and it is currently being evaluated by the RAF.

e. Materials Department, RAE, has produced a novel design of differential eddy current probe which when used with a micro-processor or mini-computer can detect small cracks yet minimise the effect of factors such as lift off. There is considerable potential for development especially in the use of pattern recognition techniques to characterise defects. The possibility of employing this as an alternative to the ultrasonic probe in the Pantatron scanner is being explored.

f. An MOD contract has been placed with the Cranfield Institute to co-ordinate the various activities in this field by ensuring that suitable specimens are made available and all promising techniques are evaluated. In parallel with this they are exploring new avenues of approach to the problem. In order to define the current situation a meeting of interested specialists was held at Cranfield on 2 November 1978.

3.2 Characterisation (in Terms of Size and Shape) of Surface Breaking Cracks, Including those in Fastener Holes with the Fastener Removed

In the case where maximum permissible crack sizes are known, and are of such a length that they would not easily be detectable by eye, it is sufficient to know that cracks up to this size can be found by NDT. However, there are a number of situations in which it is necessary to be able to specify the size of crack that must be detected in defined critical areas:

a. In the case where a safe-life item is being inspected with a view to removing the small amount of possible fatigue damage, the size of the defect is required so that the correct amount of material can be removed before applying a modification.

b. If the critical crack length is such that being able to detect a small defect would allow a sufficiently long interval between inspection, one needs to establish the minimum size and shape of defect which can be found.

c. In the case where a crack is in a skin sandwiched between other components and this is shown to break through a hole, we would need to know the crack length.

For cracks emanating from, or breaking into, a hole it is usually sufficient to know the depth down the hole and the length along the surface since, in the absence of stress corrosion the shape connecting these two dimensions can be assumed with sufficient accuracy. For many surface breaking cracks, however, it is necessary to know the surface length, depth and orientation to the surface.

Techniques for the detection of such cracks are of course already available but the sensitivity attainable and the reliability with which this can be done are largely undefined. The USAF "Have cracks will travel" programme[4] revealed a disturbingly wide divergence in performance between operators using nominally the same techniques and equipment. The programme showed that the performance of the operators could not be correlated with the training given or with the years of experience. It is therefore much to be regretted that the RAF, who (unlike the USAF) use a selection procedure based on operator aptitude, did not follow the Sub-Committee's recommendation that they avail themselves of the opportunity to take part in this programme. Other aspects which have not so far received much attention are the effect on the response of the NDT technique of factors such as the topography of the fracture surface (which will be dependent on the type of fatigue damage) and the magnitude of the stress tending to open or close the crack at the time of inspection.

The actions taken to date may be summarised as follows:

a. A limited range of flat plate and bore hole specimens containing fatigue cracks have been produced at RAE and by using visual inspection followed by destructive inspection the probable range of crack sizes and geometries has been established.

b. An MOD contract has been placed with Brunel University to develop improved eddy current techniques by examining the changes in the complex impedance pattern as the probe traverses a crack. A meeting of interested specialists was arranged by Brunel University and was held at RAE on 22 February 1979.

c. Informal liaison has been established with the NDT Centre, Harwell, to examine the potential of ultrasonic crack sizing on the above specimens.

d. Similar liaison has been established with University College on a novel ac potential drop instrument now being developed commercially.

e. An MOD contract has been placed with BAe (Warton) to produce a more comprehensive range of fatigue cracked specimens and to apply all currently available NDT techniques in order to establish limits of detectability. Sufficient numbers of similar specimens will be available to provide an estimate of technique reliability.

f. The question of second layer cracking has been discussed and a further contract proposal to study the use of low frequency eddy currents is anticipated.

g. A meeting on the general issue of crack sizing in aircraft structure components will be organised by BAe (Warton) at an early stage in the contract.

3.3 Detection of Cracks in Critical Structural Components Inaccessible to all Conventional NDT Techniques

It has proved particularly difficult to define this problem in terms that were sufficiently concrete for R&D programmes to be based upon them. However, in order to investigate whether there were avenues deserving further exploration a meeting was held at BAe (Warton) on 26 July 1978 at which these problems were aired and suitable structures made available for examination[5]. The opinions of invited NDT specialists, including a number from outside the aerospace field, was sought and this resulted in the identification of a number of areas worthy of further investigation, and these are now being pursued.

Actions taken to date are as follows:

a. An MOD funded feasibility study has started at Harwell to investigate the potential of micro-focus X-ray equipment for defect detection on practical aircraft components. This will include a comparison of high definition fluoroscopy and film techniques.

b. The question of providing a "structural fuse" in the form of a device which could be installed in an inaccessible area, and which would provide a monitorable response when a defined type of failure or degradation occurred, is being pursued. In particular discussions have been held between RAE and the National Maritime Institute on the possibility of joint funding of research on optical fibres as crack detectors. These would be bonded to the surface of a component in some desired fashion (or laid into a composite) and would crack when a failure occurred. Techniques are available not only to detect the fibre failure but also to locate the position of the break along its lengths. Some work is currently in hand at the Cranfield Institute of Technology.

c. Improved methods of visual inspection such as steerable or guided fibrescopes are being investigated.

3.4 Detection of Corrosion

Corrosion has proved to be a serious problem in a number of the aircraft operated by the RAF and it is estimated[6] that the RAF expended more than 168,000 man hours in 1975-1976 on corrosion rectification, and that if present trends continue future figures may be well in excess of this. There is therefore a need to detect corrosion at an early stage before the costs of rectification become too high. A good deal of corrosion has been found by visual inspection, and the improved visual methods referred to above will undoubtably contribute also to corrosion detection, but there is still a strong need for techniques that will find hidden corrosion.

Significant progress has been made with the use of low frequency eddy currents[7] but present indications are that there are still a number of areas on military aircraft for which these techniques are not appropriate.

Neutron radiography does offer some prospect of providing information about inaccessible areas and CSDE and AWRE have been collaborating on an investigation of its potential on practical aircraft structures; a report on this is being prepared. Progress on this programme is under continuous review by the MOD Working Party on Neutron Radiography. Beyond this, however, there is a lack of new approaches, although a TTCP Working Party on Aerospace Corrosion has been proposed, and this would include consideration of NDT techniques.

3.5 Non-Destructive Measurement of Residual Stress

Residual stresses can arise in many different ways during the manufacture and assembly of aircraft components. They cause difficulty in machining components such as forgings to size. Tensile residual stresses reduce fatigue life because of the increase in mean stress and can lead to stress corrosion in susceptible materials. Conversely, compressive residual stress at a surface can be beneficial and is often deliberately induced. The Action Group identified many cases where a rapid reliable technique for measuring residual stress during aircraft manufacture would be valuable, and there is occasionally a requirement for in-service measurement.

X-ray diffraction methods have been used in the laboratory for many years, but have not become a standard technique for NDT. A critical review of this technique was

undertaken and reported in a discussion paper[8]. Apart from the inherent limitation that the X-rays used for crystallographic work penetrate only a very thin surface layer, where the residual stress may be anomalous, the deterrents are the cost, bulk and immobility of the equipment, the time taken to make the measurements, and the complicated calculation required to obtain the results. Work in progress elsewhere seems likely to remove many of these practical difficulties, and the Sub-Committee did not consider it necessary to initiate any additional work on the same lines.

Residual stresses affect the velocity of ultrasonic waves, but to a far smaller extent than the variations in crystal orientation which occur in all structural alloys, and initially the phenomenon did not appear attractive as the basis for an NDT technique. However, a recent paper[9] shows how the effects of stress and preferred orientation can be uncoupled if it is known that they have a different spatial symmetry, and this new approach looks feasible for some applications. Unlike X-rays, ultrasonic methods are not limited to a surface measurement.

No other phenomena have been found which offer a good prospect of general application.

Actions taken to date are as follows:

a. A small experimental programme in Materials Department, RAE has shown that it is not possible to secure greater penetration by using harder radiation in the conventional X-ray technique. Some unconventional methods which might offer a small improvement in penetration are being considered at a low level of effort.

b. BAe (Manchester) are proposing to make existing static X-ray equipment suitable for use in NDT, to acquire field experience.

3.6 Inspection of Bonded Joints

In the early Sub-Committee discussions the importance of assembly by structural adhesive bonding was emphasised the more particularly because for such structures the only certain approach to proof of their integrity would be by NDT means. A Working Group was therefore set up in conjunction with City University to consider the problems and to assess any areas of study to which contributions could be made. The discussions exposed the position that one of the primary aspects of the integrity of adhesive bonding on primary structures was the long term environmental behaviour. This was thought to be related to both the nature and quality of the surface immediately prior to bonding and to the behaviour of the adhesive itself.

Few NDT instruments had been developed for adhesive bond interrogation; but arising from the three meetings of the Group, study has been directed to the application of existing techniques of NDT examination to assess their sensitivity or otherwise to sensing features related to environmental degradation of the joint. This includes the study of ultrasonic spectroscopy by City University. The relationship of the Fokker contamination meter response to subsequent joint behaviour (when used as a quality assurance tool in bond manufacture) and studies of the response of the Fokker bond tester relative to the influence of environment on the bonded joint. Contracts to study all these aspects are under way, the latter two being at BAe Hatfield. This work is of course being done in parallel with known studies of the adherend surface by various techniques which are the subject of contracts arising from other joint MOD/SBAC Committees.

The work of City University has resulted in the conclusion that there are features in the frequency spectrum or in the cepstrum that may be used to characterise the

condition of the adhesive and the interface; a final report on this is now being prepared. In order to investigate the practical implementation of these conclusions a contract has been placed with BAe Weybridge to apply these techniques to specimens in an environmental test programme.

All of the studies relate to aluminium alloys and titanium. The latter being particularly related to the carbon fibre composite - titanium programme and include several apparent chemical types of adhesives as the response is thought to be different for the different chemical types that are included in airframe construction. It is hoped that the results of these studies all now at advanced stages will be of direct value in the preparation of the bonded assemblies on the one hand and the monitoring of the structural integrity in service on the other. At present the state of a joint in service cannot be completely assessed except to be aware when separation has already occurred.

4 OTHER PROBLEM AREAS

A number of secondary problem areas have been discussed and these are listed with brief comments in Reference 2. In general these problems were insufficiently well defined or of such limited importance that no action was considered to be justified at this stage. In the case of the problem of detecting machining damage in titanium alloys, however, it was agreed that NDT development was necessary but it was considered that any research programme would have to be closely integrated with the related programmes on the materials and fatigue aspects. A proposal for work on surface conductivity has therefore been prepared by BAe (Hatfield) as part of the Fatigue Research Advisory Group's surface effects programme.

Future problem areas were largely related to the inspection of components fabricated from composite materials and the Sub-Committee originally considered that research on these topics was well in hand. Several MOD funded contracts, have, however, recently been completed and only limited R&D programmes are currently planned in this area. The Sub-Committee was surprised to note that no provision has been made for the development of in service inspection techniques or methods of monitoring long term degradation.

5 GAS TURBINE ACTION GROUP

This Group is not formed only from Members of the Sub-Committee but consists of representatives from the RAF, SBAC, Rolls Royce and MOD(PE); it has met several times and visited a number of organisations in order to see the NDT techniques in use at the present time and to discuss current problems and possible future developments. In particular they have been concerned with identifying areas where the Gas Turbine NDT problems differ significantly from those in airframes. The conclusions of the Action Group are set down in a recently issued report[10]. This report discussed the methods of NDT currently employed by both manufacturers and users, identified current problem areas and made recommendations for future work, giving an order of priority. Mention will only be made here of the topics assigned the highest priority.

It was concluded that there is an immediate need to develop a better understanding of the scientific principles behind ultrasonic probe design and manufacture in order to improve their reliability, reproducibility and resolution capabilities. Also the manufacture of ultrasonic testing equipment that incorporates advanced signal processing techniques and is capable of contour following should be encouraged. The above developments are principally aimed at close-to-form forgings etc, especially for new processing routes such as powder metallurgy and isothermal forging. A further high priority area is the inspection of inertia bonds.

The Sub-Committee endorsed the above report but considered that there was scope for better definition of the differences between the airframe and gas turbine problems. At present it would appear that the most obvious difference lies in the scope for improved automation of NDT techniques for gas turbines.

The principal action taken to date is that NGTE have placed a contract with the NDT Centre, Harwell, to develop improved ultrasonic problems and new ultrasonic techniques.

6 OTHER SUB-COMMITTEE ACTIVITIES

6.1 Visit to the NDT Centre, Harwell

The NDT Centre is the leading laboratory for advanced NDT in the UK and the Sub-Committee therefore deemed it advisable, once it had adequately defined the problem areas, to present them for comment by the Centre. Accordingly the Sub-Committee paid a visit to Harwell on 6 December 1976. After an initial presentation of the aerospace NDT problem areas the Sub-Committee visited a number of areas of the Centre and was shown ongoing research programmes that were considered to be relevant to the aerospace field. The day concluded with a general discussion and Harwell were invited to submit proposals for work on the defined problems. In fact no proposals were immediately forthcoming, but as was noted in earlier sections, some MOD funded work is now under way.

6.2 Acoustic Emission Specialists Group

The possibility of using the acoustic emission technique to assist in tackling some of the defined problems was discussed several times at early meetings of the Sub-Committee and it was concluded that, whilst this technique alone did not provide a solution to any individual problem, it could contribute significantly in a number of areas and its potential in the aerospace field should therefore be explored. Accordingly a number of specialists from various interested groups within MOD(PE) and SBAC were invited to form an Acoustic Emission Specialists Group to investigate the problems involved in applying AE to aerospace structures.

The first meeting, which was held on 16 August 1977, reviewed the current activities in the field, discussed the requirement for standardisation or characterisation of instrumentation in order to permit a meaningful exchange of data between laboratories, reviewed the limited amount of AE data available on aircraft aluminium alloys and discussed the special problems involved in monitoring aerospace structures. It was concluded that, if AE research were more closely integrated with ongoing programmes of fatigue testing, then there could be considerable mutual benefit. Accordingly a paper[11] was prepared summarising this situation and it was presented to the Fatigue Research Advisory Group in January 1978. There has been little direct response to this approach, apart from a small collaborative programme between Materials and Structures Departments at RAE. In general, however, interest in AE within BAe does appear to have increased significantly in the past year.

A second meeting was held in April 1978 at which the topics were updated and the results of some structural tests were presented. RAE had in the meantime decided to proceed with the development of a mobile, computer based, AE system based on the AMTE system but tailored to meet the specialised requirements of aerospace structures; it was intended that this should be made available as widely as possible to other members of the group.

Since then BAe (Woodford) have taken delivery of a commercially available system performing many of the same functions. A further meeting of the group is planned.

6.3 Acoustic Impluse NDT

It is well known that the overall acoustic properties of a component can in certain circumstances be significantly changed by quite small amounts of damage and the possibility of developing an up-to-date version of the "wheel tapper" has been raised in many quarters. Applications made to date have however been on components of essentially simple geometry although quite sophisticated computer based analysis procedures have been employed to extract the relevant features of the response to an externally applied impulse. There are three main parameters of interest:

i the frequency of particular modes of vibration

ii the damping characteristics

iii the goemetric positions of nodes and anti-nodes.

One such procedure is available at the NDT Centre, Harwell, using the DAISY suite of computer programs and discussions were held with RAE to assess the potential of these methods for the defined problem areas. It was concluded that evaluation on components such as turbine blades should be attempted first, since these were of relatively simple geometry and a large number of similar components was available.

Shortly after this, reports were received from several quarters of a device developed by Daedalean Associated Inc (DAI), a small company in Maryland, USA, under funding from the US Navy ONR. It was claimed that the DAI device could detect and locate incipient crack growths at a location remote from the sensors. Such information as was available indicated that the DAI device involved a coded imput signal that was selected for transmission into the structure and a receiver, or receivers, that fed a computer based data analysis system to give a measure of the dynamic structural response of the component. The parameters measured, however, appeared to be those listed above.

The Sub-Committee considered that these claims should be further investigated and decided that the best way to do this would be to call a meeting at which all relevant UK experience would be reviewed and all information on the DAI device presented for discussion. Accordingly a meeting[12] was held on 5 July 1978. This meeting concluded that there was reason to doubt the claims made by DAI and initiated a number of lines of enquiry in the USA in an attempt to obtain more concrete evidence. Replies received to date confirm the meeting's view that the device is of limited application and could not be used on components of any complexity. The meeting also proposed a short series of simple specimens which could be evaluated by Harwell so as to provide a foundation for any further development. These specimens have now been prepared and sent to Harwell.

7 TECHNIQUE DEVELOPMENT

In this report the activities of the Sub-Committee have largely been presented on a problem by problem basis; discussions have, however, also been held on the potential of individual techniques without necessarily relating them to a specific problem. In the case of the acoustic emission and acoustic damping techniques it was considered that these merited special meetings and these have been reported in Sections 6.2 and 6.3. There were in addition some areas which the Sub-Committee considered to have potential and wished to see encouraged but which have not yet formed the basis of a separate meeting.

7.1 Optical Methods

Although optical holography technique has been available for a number of years its application to aerospace NDT problems has been rather limited. In the UK it has principally been used on honeycomb and other sandwich panels to detect de-bonding and on filament wound pressure vessels. A series of tests[13] were performed at RAE on a number of prototype CFRP skinned wing-tips and the technique was shown to be capable of detecting quite small anomalies in the structural configuration. Interpretation of the fringe patterns was initially rather difficult, but experience on a particular component allowed quite subtle differences to be revealed.

The Sub-Committee considered that these results were very encouraging but stressed the need to develop a system better adapted to production or in-service inspection. An MOD contract has now been placed with Loughborough University to produce an improved version of their electronic speckle interferometer system, engineered so as to provide a dedicated unit for NDT purposes. This unit will have the big advantage that the reference hologram will be available instantaneously since it is stored electronically rather than photographically. Thus a large number of deformation mechanisms can be explored in order to find the optimum method of revealing a defect. If successful, then consideration will be given to a pulsed laser system for field use.

7.2 Signal Processing

Although NDT equipment has improved in sensitivity, reliability and ease of use in recent years there has been surprisingly little advance in the nature of the data collected and in its method of presentation. It is now generally recognised that the received signals from many techniques contain a good deal more information than is currently being extracted, and that signal processing techniques can often be devised that will reveal this information. The advent of comparatively cheap micro-processors and mini-computers means that such processing procedures are now feasible, but there is a need to develop suitable techniques. Some form of signal processing is clearly possible whenever the data from a technique can be converted into an electrical signal, but there are four techniques where signal processing appears to have the greatest potential namely ultrasonics, eddy currents, radiography and acoustic emission. In this section each of the four principal applications will be considered in turn.

7.2.1 Ultrasonic Applications

The interaction of an ultrasonic wave with a defect often gives rise to a complex series of waves, even in a simple specimen geometry, and considerable care and skill is required in interpreting the usual 'A Scan' presentation. There is the potential to ease this task by suitable signal processing procedures varying from simple signal averaging, to improve the signal-to-noise ratio, to frequency analysis and de-convolution techniques. The importance both of understanding the wave-defect interaction and of developing signal processing procedures has been recognised by the US Department of Defense, and the main thrust of the ARPA/AFML programme on Quantitative Non-destructive Evaluation[14] is aimed at these topics.

The Sub-Committee agreed on the importance of these topics but considered that it was neither practicable nor necessarily advisable to attempt to set up anything comparable to the US programme. Instead, activities have been started in a number of areas which should, if suitable liaison is maintained, make a worthwhile contribution to the practical implementation of these techniques and these are summarised below:

a. Support is being given to the advanced ultrasonics group in the Physics Department, The City University. A contract on the use of ultrasonic spectroscopy for adhesive bonded joints has just finished and proposals for a consortium to support broader based work are being considered. MOD funded work on the development of numerical analysis procedures to model the interaction of ultrasonic waves with defects is proving very successful.

b. RAE is now using computer procedures to manipulate ultrasonic data the initial aim being improved defect identification in composites.

c. A contract has been placed with BAe (Weybridge) to investigate the use of computer based ultrasonic frequency analysis procedures (based on Item (a) above) to monitor environmental degradation in adhesive bonded joints.

d. The Cranfield Institute are using computer based procedures on ultrasonic data from cracks under fasteners.

e. Although not directly related to the work of the Sub-Committee it should be noted that PERME (Westcott) are very active on similar problems and in particular on the use of ultrasonic diffraction techniques to size defects in the interior of components; they also fund related extramural programmes. In addition PERME provides the UK leader for a TTCP collaborative group (PAG3(b)) on advanced ultrasonics.

7.2.2 Application to Radiography

Various image enhancement techniques are available, either on-line with fluoroscopy or post-test when using film, that bring out particular features of conventional grey tone photography and some of these were demonstrated to the Sub-Committee during its visit to the NDT Centre, Harwell. In general the Sub-Committee concluded that the techniques that were available (although not necessarily employed in practice) were quite adequate for radiography as currently used in aerospace applications.

7.2.3 Application to Eddy Current Techniques

The development of scanning eddy current methods is taking place at RAE. The full potential of these methods can only be realised by the use of mini-computers for control, data acquisition, and, most significantly, data analysis. The last of these involves the application of complex signal analysis and pattern recognition techniques which enable better use to be made of all the data that is available by measurement. Greatly improved performance results from the ability to recognise features that would otherwise be lost in noise. The application of these principles to the detection of cracks under installed fasteners has demonstrated the potential of this approach.

7.2.4 Application to Acoustic Emission

Computer based systems which capture acoustic emission pulses from arrays of transducers, store the amplitude data and perform location procedures have been available for some time and, as was noted in Section 6.2, RAE is due shortly to take delivery of such a system specifically designed for aerospace applications. However, the use of computers to characterise failure events by capturing the analysing the electrical time-domain signal produced by the event has received attention only be a few groups.

The NDT Centre, Harwell, has received MOD support on this topic for a number of years and by using a special design of specimen they have been able to distinguish between different types of failure event. This has, however, been essentially a laboratory

procedure. Work on de-convolution procedures to enable the strong modulation effects produced by real components and practical transducers to be eliminated is being actively pursued by RAE in collaboration with AMTE (Holton Heath). Progress on these topics is reported back to the Sub-Committee via the Acoustic Emission Specialists Group.

8 RELATIONSHIP BETWEEN NDT RESEARCH FUNDED BY MOD AND BY SBAC COMPANIES

During the early part of the life of the Sub-Committee a large number of problems were tabled by the RAF and SBAC Members and from discussion of these it was possible to establish priorities. In the case of a few the most urgent problem areas it was considered necessary to initiate some research work immediately, but in the majority of cases it was decided to investigate which organisations were best suited to the work required. In particular, MOD were anxious to establish which of the SBAC Companies were likely to submit contract proposals in this field and whether or not there was a possibility of duplication of effort. To this end a provisional list of proposals for location of NDT programmes was issued by SBAC in May 1976, and updated in October 1976. The Sub-Committee were, however, unable to relate this directly to the then current SBAC 'Shopping List' and the Sub-Committee requested further clarification. As a result of this detailed lists of proposed Contract Submissions, cross referenced to the 'Shopping List' and indicating likely dates and duration, were submitted by BAC and HSA in April 1977. RAE discussed these with DR/Air and DR/Mat then replied to SBAC in May 1977 pointing out some areas of potential duplication of effort and indicating preferences. As a result of this some proposals were submitted and contracts placed as noted in earlier sections of this report.

Further rationalisation took place more recently as a consequence both of the creation of British Aerospace and of the devolvement of responsibility for funding of extra-mural contracts to RAE and NGTE. A document[15] has now been prepared which reviews all current and proposed NDT research programmes at the various BAe sites and indicates whether funding is expected to come from BAe or MOD sources. This document, which includes all items on the current 'Shopping List'[16], has been discussed by the Sub-Committee. Comment has also been made by WHL who have identified areas of mutual interest, outlined NDT activity currently being funded under the demonstrator programme and listed some specific future requirements. Requirements for research funding by Rolls Royce have been discussed by the Gas Turbine Action Group; the areas of current interest are detailed in the Minutes of the 5th Meeting of this Group. Beyond this, however, there has been no input from other SBAC Companies.

9 SUMMARY AND CONCLUSIONS

9.1 Mechanisms have been established which have:

a. Satisfactorily defined the problem areas to date,

b. provided the means of update these problems as appropriate.

9.2 A number of Action Groups have been set up; these advise on the requirements for research programmes to be initiated in their respective areas and ensure that adequate liaison and co-ordination is achieved.

9.3 Specialist meetings have been held on a number of topics and, where appropriate, comment and contributions have been sought from experts outside the aerospace field.

9.4 The majority of the on-going and proposed NDT research programmes in the aerospace field funded either by MOD or by SBAC Members have now been identified. It should therefore now be possible to ensure efficient coverage of the required topics.

9.5 Progress in R&D is severely impeded by a shortage of suitably trained manpower; this is far more important than the provision of funding which is at present adequate.

9.6 There is very little formal training available in the scientific aspect of NDT. This is indicative of a lack of demand for such training probably resulting from:

a. A reluctance to release scarce manpower for anything but short term training,

b. the poor image of NDT as a career for graduates.

9.7 The small size of the UK Manufacturers of NDT equipment means that they are not geared to R&D work and thus the simple injection of funds tends not to be effective.

9.8 Interest in NDT research at Universities has increased significantly in recent years and this should pay dividends in the future.

10 RECOMMENDATIONS

10.1 More effort should be made to estimate the cost effectiveness of NDT procedures. The Sub-Committee is aware of the difficulties involved in obtaining data of this nature, but without such guidance it is very difficult to decide either what total R&D effort can be justified in the NDT field, or what priority to give to individual items.

10.2 The R&D aspects of aerospace NDT should be further separated from the routine inspection facilities and put onto a more scientific basis. This will mean the recruitment of suitable personnel and the provision of facilities to tackle topics such as those noted in 10.6 below.

10.3 Collaboration with areas of advanced NDT outside MOD should be improved, at least at a working level. At present communication is largely maintained through meetings organised by various learned societies but the Sub-Committee considers that this is not sufficient.

10.4 If sufficient common ground can be identified by (10.3) then the feasibility of joint funding should be explored.

10.5 The Sub-Committee fully supports the current efforts at international collaboration in this field and recommends that ways of providing better communication at a working level be investigated. In particular it is considered that, whilst routine information exchange under TTCP is helpful, a great deal more is likely to be achieved by direct contact such as exists in the two Action Groups on NDT topics formed by TTCP Sub-Group P.

10.6 More effort should be put into investigation of the potential of computers and micro-processors for NDT. Their use both for signal processing and automatic control should be explored.

10.7 The problems of in-service inspection of components fabricated from composite materials and the monitoring of long term degradation should be given more urgent attention.

Appendix A

TERMS OF REFERENCE

1 To review current and probable future requirements for assessing the integrity of materials, components and structures involved in the design-production-service cycle of Defence equipment.

2 In relation to such requirements, to review current and new scientific phenomena for their application to NDT.

3 To recommend to the parent Committee lines of research that will lead to more effective and more economical non-destructive evaluation (NDE).

ADDITIONAL TERMS OF REFERENCE ADDED BY THE PARENT COMMITTEE IN OCTOBER 1977

4 To review, assess and co-ordinate NDT research activities in the aerospace field.

5 To act as a focal point for information exchange on these topics.

Appendix B

CURRENT MEMBERSHIP

Name	Organization	Representing	Serving on Action Groups
Dr D E W Stone (Chairman)	Structures Department, RAE	MOD(PE) Co-ordinating Committee for NDT	A,CF
Mr R M Hare	BAe (Hatfield)	SBAC Structures Research Sub-Committee	R
Mr G B Evans	BAe (Hatfield)	SBAC Metallic Materials Sub-Committee	A,R
Mr T Sharples	BAe (Warton)	SBAC (Military Aircraft)	CS
Mr C W Hope	Westland Helicopters Ltd	SBAC (Helicopters)	A
Wg Cdr B Robson	Air Eng 30 (RAF)		
Sqn Ldr T McKenna	Air Eng 30d (RAF)		CF,CS
Sqn Ldr M Gulliver	CSDE		CF,CS,G
Dr J N Eastabrook	Materials Department, RAE		R,CF
Dr T P Hobin	MOD(PE), Mat R Co-ord	TTCP and other International Collaboration	G
Mr M J Weaver	Materials Science Dept, NGTE		G,CS
Mr D L Mead (Secretary)	Structures Department, RAE		

Key to Action Groups

A Adhesive Bonded Joints
CF Cracks Under Installed Fasteners
CS Crack Sizing of Surface Breaking Cracks
G Gas Turbine
R Residual Stress

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17. Abstract

The establishment of a working party on aerospace NDT problems and its subsequent conversion into a Sub-Committee of the MOD Co-ordinating Committee for NDT is described. A number of problem areas are discussed and actions taken towards their solution are outlined. Other activities of the Sub-Committee are summarised and some techniques that are considered to have potential are identified. Brief conclusions are drawn and some recommendations are made.